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Abstract: In the last 50 years, rangelands in the Central Anatolian Region of Turkey have been converted to cropping lands, which has negatively accelerated vegetation change, resulting in overgrazing and poor condition and productivity. In these steppe rangelands, to develop a rational basis for making restoration and management decisions, the vegetation structure must be well understood. Thus, the objectives of this study were to: (1) define vegetation patterns through assessing spatial distribution of the plant species and groups, (2) evaluate the relationships between vegetation and environmental aspects and range condition, and (3) outline possible restoration implementations. Therefore, a study was carried out in Paşalı village rangelands of Nevşehir province in 2004. Thirty-seven sites in 733 ha range area were surveyed, and 78 plant species were identified. Most of the identified species were forbs (60), followed by grasses (11) and shrubs (7). The major range species were *Thymus sipyleus* (7.2%), *Festuca valesiaca* (6.9%), and *Bromus tomentellus* (6.4%). Range condition scores fell between 1.20 to 3.40, representing very poor to poor condition. The positive relation of *Bromus tomentellus* cover, as an enviable perennial grass, with the range condition score ($P < 0.001$) can pave the way for the condition improvement. Our classification result displayed several groups of species, although there were not many environmental differences, indicating that the groupings are most likely to have occurred due to the spatially-varying grazing intensity. In order to increase the proportion of desirable species in this overgrazed rangeland, the implementation of deferment grazing especially until after seed setting should be essential.

Key Words: Semiarid, steppe-rangelands, vegetation-pattern, Central Anatolia, Redundancy Analysis

Orta Anadolu Step Meralarında Vejetasyon Yapısının Değerlendirilmesi İçin Pilot Çalışma

Özet: Türkiye'de, Orta Anadolu Bölgesinde geçen elli yılda geniş mera alanları tarım arazisine dönüştürülmüş ve bu durum vejetasyondaki değişimi olumsuz biçimde etkilemiştir. Sonuçta, otlatma alanları aşırı otlanan, zayıf ve düşük verimli hale gelmiştir. Bu step meralarında, iyileştirme ve amenajman çalışmalarının esaslarını geliştirmek için vejetasyon yapısının iyi bilinmesi gerekir. Dolayısıyla, bu çalışmayla; (1) bitki tür ve gruplarının dağılımını değerlendirerek vejetasyon paternini belirlemek, (2) mera durumu, çevresel özellikler ve vejetasyon arasındaki ilişkileri ortaya koymak, (3) muhtemel iyileştirme uygulamalarını önermek amaçlanmıştır. Bu amaçlar doğrultusunda, 2004 yılında, Nevşehir İli Paşalı köyü meralarında bir çalışma yürütülmüştür. 733 ha mera alanı üzerinde 37 durakta yapılan vejetasyon sörveyleri sonucunda toplam 78 mera bitki türü tespit edilmiştir. Geniş yapraklı otsu bitkiler 60 türle en fazla tür sayısına sahipken onu 11 türle buğdaygiller ve 7 türle çalılar izlemiştir. Mera durum skoru 1.20 ile 3.40 arasında değişirken sırasıyla çok zayıf ve zayıf sınıfları temsil etmişlerdir. *Thymus sipyleus*, *Festuca valesiaca*, ve *Bromus tomentellus* önemli mera bitki türleri olurken, bu türler sırasıyla %7.2, %6.9, ve %6.4 bazal kaplama değerine sahip olmuşlardır. Çok yıllık önemli bir buğdaygil bitki türü olarak *Bromus tomentellus*'un kaplama oranının mera durum sınıfıyla olumlu önemli bir ilişkiye sahip olması ($P < 0.001$) mera durumunun iyileştirilmesine imkân verebilir. Çevresel faktörler bakımından fazla bir farklılık olmasa da, sınıflandırma sonucunda muhtelif bitki grupları ortaya çıkmıştır. Bu da, gruplaşmanın daha çok merada değişen otlatma yoğunluğundan kaynaklandığını göstermektedir. Böyle ağır otlanan bir merada, arzu edilen bitki türlerinin oranlarının artırılması bakımından özellikle tohum bağlama sonrasına kadar otlatmanın geciktirilmesi uygulaması esas olmalıdır.

Anahtar Sözcükler: Yarı kurak, step meralar, vejetasyon paterni, Orta Anadolu, Fazlalık Analizi

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Introduction

One third of the 13.1 million hectares of grazing lands in Turkey is located in Central Anatolian region (CAR) (DİE, 2001). The CAR grasslands have been grazed intensively since the early appearance of ancient civilizations (e.g. Hittites and Phrygs). Consequently, plant populations and communities have been progressively shaped, in both an ecological and evolutionary sense by this long history of intensive grazing. In the last 50 years, large rangelands have been converted to cropping lands (Bakır, 1971, 1987; Büyükburç, 1983; Fırıncıoğlu et al., 2007), which has negatively accelerated vegetation change, resulting in overgrazing and poor condition and productivity in remaining rangelands. Typically, plant cover is only 10% and 20% and bare soil is subjected to severe wind and water erosion (Büyükburç, 1983). Tarman (1962, 1968) explained that the unproductiveness of the CAR village rangelands was due to overstocking, and heavy and early grazing. Other studies (Birand, 1943; Walter, 1956; Horn, 1970; Büyükburç, 1983) document that range vegetation composition in the CAR has become less nutritive and palatable, and there is an increase in weedy species owing to long-lasting heavy grazing. As in most of the world, steppe vegetation, which is peripherally delimited by woody vegetation of the Anatolian territory, has been exploited for grazing and intensive agriculture activities (Akman et al., 1984). In these steppe rangelands, previous investigations revealed that grazing intensity and environmental aspects are major factors controlling distribution and abundance of the dominant plant species, including *Festuca valesiaca*, *Artemisia sanctonium*, *Thymus sipyleus,* and *Poa bulbosa* (Büyükburç, 1983; Bakır, 1987; Fırıncıoğlu et al., 2007).

To provide a rational basis for making restoration and management decisions, the distribution and structure of range vegetation must be well understood. In the CAR, basic vegetation data is urgently needed to assist with the enforcement of the new range act. The goal of this study is to provide an accurate estimate of vegetation patterns and range conditions in order to generate basic information for the planning and designing of a rehabilitation project. To achieve this goal, comprehensive vegetation sampling with the use of a stratified design was initiated. A systematic, hierarchical classification of vegetation using numerical multivariate techniques was established, defining relationships between compositional and structural patterns, and key environmental variables were proposed.

The structure, functioning, and species diversity of grassland ecosystems are inter-related (Archer and Smeins 1991; Tilman and Downing, 1994) and can be altered by grazing (Huntly, 1991). Improper utilization of rangelands by over-grazing can reduce cover and diversity of native plant species (Brady et al., 1989; Cooperrider, 1991; Fırıncıoğlu et al., 2007). Condition and trend of range vegetation are a primary concern of range managers for making sound range management plans (Tueller and Blackburn, 1974). Classification of plants according to life history traits has a long tradition in plant ecology (Weiher et al., 1999). A variety of names have been given to different classifications (e.g. life forms (Raunkiaer, 1937), strategies (Grime, 2001) and functional types (McIntyre et al., 1999)), and this has resulted in groupings being based on different individual traits or groups of co-occurring traits. Plant functional types can be defined as sets of plants exhibiting similar responses to environmental conditions and having similar effects on the dominant ecosystem processes (Walker, 1992; Noble and Gitay, 1996). Therefore, their identification and abundances should be highly relevant to rangeland restoration planning.

Classical succession theory, still widely utilized, suggests that rangeland systems are best described as predictable linear sequences of plant communities, sequentially changing in orderly response to control variables like grazing, fire, precipitation, and competition. Some range managers use the range condition model (or climax vegetation model) (Dyksterhuis, 1949) to evaluate rangelands and guide grazing management. This system identifies range sites, and then links successional stages to the degree of grazing impact. This classical theory continues to be useful in mesic systems (Martz et al., 1999; Paine et al., 1999; Carlassare and Karsten, 2002); however, it has proven inadequate in arid and semiarid systems, where environmental variability dominates vegetation dynamics (Westoby et al., 1989; Illius and O'Connor 1999; Oba et al., 2000; Sharp and Whittaker, 2003). Accordingly, the state and transition model has been proposed to account for widely observed nonlinear, non-equilibrium plant community dynamics (Westoby et al., 1989). Grazing animals or environmental fluctuations may trigger vegetation changes that are discontinuous and irreversible in arid rangelands. Regarding conflicting ideas on vegetation succession and limited information on the climax vegetation of the rangelands in Turkey, Gökkuş et al. (1995) suggested that range condition class can be best determined with the use of plant quality value, rather than using proportions of decreaser, increaser, and invader species within the climax vegetation.

The instability reported for other arid regions can be seen in the CAR, causing concern about soil and vegetation degradation. Therefore, the objectives of our study were to: *(1)* define vegetation patterns through assessing spatial distribution and diversity of plant species and plant groups, *(2)* evaluate the relationships between vegetation and environmental aspects and range condition classes, and *(3)* outline possible restoration implementations.

Methods

Study Location

This study was carried out in Paşalı village rangelands in 2004, which are located 40 km northwest of Nevşehir province (Figure 1). At the time of vegetation survey, according to the records of the Nevşehir Provincial Agriculture Directorate, there were 443 Animal Units (AU) of live stock (i.e. 1 AU is equal to 500 kg live weight) from both small and large ruminants in Paşalı, though the proper range carrying capacity was estimated as 96.3 AU for the 137-day grazing season.

The semi-arid climate of the CAR is characterized by cold winters and hot summers with most precipitation occurring in winter and spring. According to long term records (from 1986 to 2004) of the Avanos County Meteorological Station, average temperature ranges from 0.4 °C in January to 24.3 °C in July, with a yearly mean of 12.1 °C, and annual precipitation is 321 mm. In 2004, average temperature varied between 1.7 °C in January to 24.2 °C in August, with a yearly mean of 12.3 °C, and annual precipitation was 323.6 mm. The predominant growing seasons in the Central Anatolian Basin are spring (March to June) and autumn (September to October).

The shallow soils in the study area are clay-loam, slightly alkaline, poor in phosphorous and organic matter, and have high potassium and lime levels. Soils are not

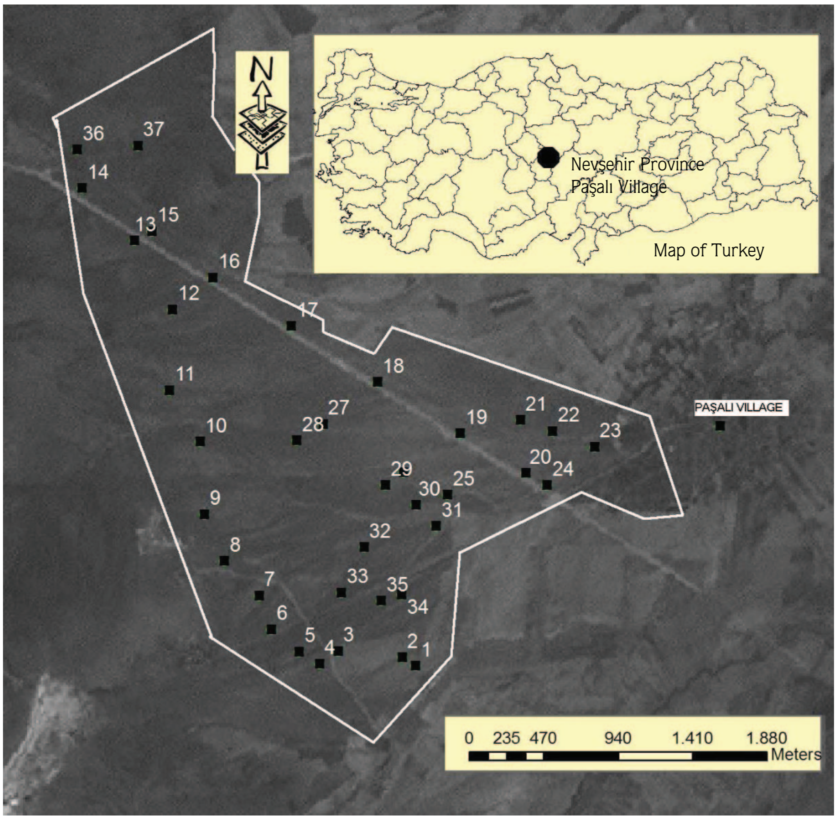

Figure 1. Satellite image of Nevşehir-Paşalı village and communal pasture area with 37 sampled sites.

salty. Village rangelands are flat and are surrounded by arable land. Village farmers communally use these native pastures, and no management practices are implemented. The native pasture lands, depending on climatic conditions and herbage availability, are grazed by sheep year-round, while cattle are grazed from April to November. In the region, after cereal harvest in Mid-July, sheep herds are moved onto cereal stubble. During the winter time, feed shortages are mitigated with cereal straw, barley grain, and some concentrates (Fırıncıoğlu et al., 1997).

Sampling procedure

Due to the relatively flat and homogeneous landscape, 37 sites scattered over the 733 ha village rangeland were regarded as a sufficient sample for this study (Figure 1). The 37 sites, covering the whole pasture area, were randomly chosen as the sampling points. The coordinate of each sampled site was determined by using a GPS instrument, and these coordinates were marked on the satellite image (Figure 1). The percent basal cover for each species and bare ground was measured with a wheel point apparatus modified with a loop (Tidmarsh and Havenga, 1955; Parker, 1951). With each turn of the wheel along a 50 m transect, the basal cover of the plant species in the ring or bare ground was recorded at 0.5 m intervals, resulting in 100 recordings at each site. Basal cover was regarded as a more appropriate measurement than crown cover, because the sampling was done under grazing conditions. The vegetation surveys were conducted during the peak growth period of the rangeland species (first week of June). Environmental variables recorded at each site were altitude, soil compactness, erosion severity, and grazing intensity. Soil conditions that could be influenced by the process of degradation were measured. Soil compaction and degree of erosion were described in classes from 1 (no compaction/no erosion) to 5 (severely compacted/severe erosion=no topsoil). An index value, as a visual estimation, was also assigned to each sampled site to describe the inferred level of accumulated grazing intensity on a scale from none = 1 (i.e. all grazeable herbage is available at the site) to very high = 5 (i.e. all grazeable biomass is removed at the site). Three soil samples were taken from the 0-20 cm soil layer at the start, middle, and end of each transect. The soil samples were combined for each site and were analyzed for pH, salt and lime contents, water saturation, phosphorous, and potassium.

Data Management and Statistical Procedures

A total of 78 plant species were identified. Plant identification was rendered according to the Flora of Turkey and East Aegean Island (Davis, 1965, 1985). Five species were only identifiable to genus. Percent basal cover of each species and bare ground in each site was measured. Plant species were grouped into functional groups (forbs, grasses, and shrubs), life spans (annuals and perennials), and life forms (geophytes, chamaephytes, hemicryptophytes, and therophytes). The life-forms are classified according to Raunkiaer (1937), as modified by Govaerts et al. (2000). This approach classifies plants in accordance with the position of their perennating buds (i.e. level of protection given to these buds) during the unfavorable growing seasons (e.g. winter cold and summer drought).

Descriptive statistics were employed for the most abundant species, plant groups, environmental variables, and biodiversity indices. To measure plant species diversity in the 37 samples, we used Shannon's index and Simpson's index as described by Ludwing and Reynolds (1988). Shannon's index (H') for a sample is the average degree of uncertainty in predicting the species of an individual chosen at random from a sample and is defined as

$$H' = -\sum_{i=1}^{S} (n_i/n)\ln(n_i/n)$$

where n_i is the cover of the ith species of S species in the sample and n is the total cover of all species in the sample. Simpson's index (λ) for a sample, which is the probability that 2 individuals selected at random will be the same species, is defined as

$$\lambda = \sum_{i=1}^{S} n_i(n_i - 1) / (n - 1)$$

The values from these indices were transformed in a method recommended by Ludwing and Reynolds (1988) and described by Hill (1973), to determine the abundant ($N1$) and very abundant species ($N2$). $N1$ was calculated as

$$N1 = e^{H}$$

and $N2$ was calculated as

$$N2 = 1 / \lambda$$

With the values from the above equations, a modified Hill's ratio was then determined as a measure of evenness (Hill, 1973). *E*5 was calculated as

$$E5 = (1 / \lambda) - 1 / e^{H} - 1 = N2 - 1 / N1 - 1$$

As *E*5 approaches zero, 1 species becomes more dominant in the total cover component. Higher values of *E*5 indicate a more even division of cover among the species in the sample area.

Gökkuş et al. (1995) suggested that the method developed by De Vries et al. (1951) for assessing range condition based on plant quality is the most suitable for use in Turkey. In accordance with plant species characteristics such as plant productivity, re-growth after defoliation, physical properties (e.g. hairy and spiny), palatability and poison content, and each plant species is valued between - 1 and + 10; with the most desired plants + 10 and poisonous plants -1. Then, the Range Condition Score (RCS) can be calculated as follows:

$$RCS = \sum_{i=1}^{S} (Bcr \times Qv) / 100$$

where *Bcr* is the ratio of the species within the botanical composition, and *Qv* is the quality value of that species. In a sampled site, the RCS of all species is summed up and divided by 100, thus giving a range condition score value for this specific site. Range condition is divided into 5 classes; very poor (0.0 - 2.0), poor (2.1 - 4.0), fair (4.1 - 6.0), good (6.1 - 8.0), and excellent (8.1 - 10.0).

Regression analysis was used to compare the species richness (number of species) with diversity indices, and to compare percent basal covers of *Thymus sipyleus*, *Festuca valesiaca*, and *Bromus tomentellus* with the range condition class and bare ground.

To investigate the correlation of vegetation and physical environmental factors, we used the canonical form of principle component analysis; Redundancy Analysis (RDA). When gradients are short, the relationship between vegetation response and environmental variables is likely to be linear (Ward et al., 1993). Results of RDA were used to ordinate species, based on their abundance and appearances, with the measured environmental variables (soil and environment). Species appearing in less than 4 sites were considered rare, and removed from the data matrix to avoid introducing unnecessary noise (Mentis, 1983). Therefore, RDA was performed with the abundances of 34 species for 37 sites. We employed CANOCO version 4.5 (Ter Braak and Smilauer, 1998) for the RDA. For the descriptive and regression analyses, MINITAB version 14 was used.

Results

The Appendix lists the 78 species identified in the study area, organized into functional groups (forbs, grasses, and shrubs), life span groups (annual, biannual, and perennial), life form groups (*geophytes*, *chamaephytes*, *hemicryptophytes*, and *therophytes*), with their occurrence number, mean cover, and quality values.

Percent cover of plant groups and bare ground, and the range condition scores for the 37 sampled sites are given in Table 1. Forbs species were most numerous (60), followed by grasses (11) and shrubs (7). There were 4 annual and 7 perennial grass species. The *hemicryptophytes* life form group had the highest number of species (49), and followed by *therophytes* (19), *chamaephytes* (7), and *geophytes* (3) (Table 1). The mean plant species for each transect was 13, ranging from 7 to 20 (Table 1).

Bare ground varied widely from 40% to 81%. Among the functional groups, forbs had the highest cover (20%), followed by grasses (16%) and shrubs (8%). For the life span group, perennial-forbs possessed the greatest cover with 18%, while the perennial-grasses had a cover of 14%. Annual grasses, comprised of invasive and noxious species, covered 2% of the range area. In terms of the life span groups, the *hemicryptophytes* acquired the greatest cover (31%), while the *geophytes* had the least (0.22%). The mean range condition score was 2.5 (poor) and varied between 1.2 (very poor) and 3.4 (poor).

Percent basal covers of the most abundant plant species are presented in Table 2. The most abundant species identified in the study area were *Alyssum pateri, Artemisia santonicum, Astragalus condensatus, Astragalus karamasicus, Bromus tomentellus, Centaurea sivasica, Convolvulus assyricus, Festuca valesiaca, Poa bulbosa,* and *Thymus sipyleus* (Table 2). None of these species appeared in all of the 37 sites. *Thymus sipyleus*, prostrate shrub, had the highest cover (7.2%), followed by a short grass, *Festuca valesiaca* (6.9%), a tall grass *Bromus tomentellus* (6.4%) and a sod forming percnnial forb, *Convolvulus assyricus* (6.0%) (Table 2). The other species had the cover values less than 3% (Table 2).

Table 1. Mean percent cover of plant groups (plant functional group; forbs, grass, and shrub and life span group; annuals-biannuals, perennials, and life form group; *geophytes*, *chamaephytes*, *hemicryptophytes*, and *therophytes*) and bare ground, and number of species and range condition scores for the 37 surveyed sites at Paşalı village rangelands (n; number of sites with plant groups, N; number of species within each group).

Attributes	n	N	Mean ± SEM	Maximum-Minimum
Functional group				
Forb	37	60	20.05 ± 1.17	6.50 - 33.30
Grass	36	11	15.71 ± 1.27	0.00 - 38.90
Shrub	34	7	8.15 ± 0.96	0.00 - 22.60
Life span group				
Annual-Biannual-Forbs	28	16	2.25 ± 0.47	0.00 - 13.000
Perennial-Forb	37	44	17.80 ± 1.12	5.60 - 29.60
Annual-Grass	13	4	2.15 ± 0.69	0.00 - 15.70
Perennial-Grass	34	7	13.56 ± 1.18	0.00 - 35.20
Life form group				
Geophytes	6	3	0.22 ± 0.09	0.00 - 2.00
Hemicryptophytes	37	49	30.48 ± 1.69	7.70 - 51.40
Chamaephytes	36	7	8.85 ± 1.07	0.00 - 22.40
Therophytes	33	19	4.38 ± 0.76	0.00 - 15.70
Bare ground	37	-	56.21 ± 1.66	39.80 - 80.80
Number of species	37	78	12.97 ± 0.47	7.00 - 20.00
Range condition scores	37	-	2.53 ± 0.09	1.20 - 3.40

Table 2. Mean, standard error of means (SEM), range and number of appearances (N), percent basal covers of the major plant species in the 37 sampled sites in Paşalı village.

Species	Code	N	Mean ± SEM	Range
Alyssum pateri	ALPA	29	2.70 ± 0.29	0.90 - 6.50
Artemisia santonicum	ARSA	17	2.05 ± 0.21	0.90 - 3.70
Astragalus condensatus	ASCO	25	2.84 ± 0.56	0.90 -14.00
Astragalus karamasicus	ASKA	20	1.99 ± 0.26	0.90 - 4.80
Bromus tomentellus	BRTO	28	6.39 ± 0.69	0.90 -14.00
Centaurea sivasica	CASI	22	2.99 ± 0.42	0.90 - 8.30
Convolvulus assyricus	COAS	30	6.02 ± 0.92	0.90 -20.40
Festuca valesiaca	FEVA	32	6.85 ± 0.89	0.90 -19.00
Poa bulbosa	POBU	21	2.82 ± 0.44	0.90 - 7.50
Thymus sipyleus	THSI	32	7.23 ± 0.90	0.90 -18.90

Measures of plant biodiversity (indices calculated from percent cover of plant species), as an indication of the species richness, are presented in Table 3. For the 37 range sites Shannon's index was 2.1, while Simpson's index was 0.14. The *N1*, *N2,* and *E5* indices were 8.72, 8.00, and 0.91, respectively.

As the number of species (species richness) increased, *H'* (Shannon's index) also increased significantly ($P < 0.001$), whereas (Simpson's index) considerably decreased ($P < 0.01$), where *E*5 (evenness index) did not change ($P = 0.505$) (Figure 2). Bare ground was negatively correlated with *Bromus tomentellus* ($P < 0.01$), *Festuca valesiaca* ($P < 0.05$), and *Thymus sipyleus* ($P < 0.05$) (Figure 3). The association between range condition score and *Festuca valesiaca* cover was best described by a quadratic equation ($P < 0.05$), indicating that the sites at the opposite extremes of very poor and poor conditions had reduced *Festuca* cover (Figure 4). *Thymus sipyleus* and *Bromus tomentellus* were positively correlated with the range condition class ($P < 0.001$) (Figure 4).

Table 3. Mean, standard error of mean (SEM), and range of some diversity indices for the 37 sampled range sites in Paşalı village.

Index	Mean ± SEM	Range
Shannon's index (H')	2.13 ± 0.05	1.20 - 2.67
Simpson's index (λ)	0.14 ± 0.01	0.06 - 0.27
N1	8.72 ± 0.39	3.30 - 14.41
N2	8.00 ± 0.48	3.75 - 16.42
E5	0.91 ± 0.014	0.48 - 2.04

Environmental variables, such as soil characteristics, grazing intensity, soil compactness, erosion severity, and altitude for the 37 surveyed sites, are presented in Table 4. In the 37 sites, among these environmental variables lime, phosphorous, and potassium contents in the soil ranged from 6.50% to 18.60%, 38.00 to 123.60 kg ha^{-1}, and 140.40 to 600.00 kg ha^{-1}, respectively (Table 4). Grazing intensity varied from 1.00 (none) to 5.00 (very heavy) (Table 4).

Results of the redundancy analysis (RDA) are summarized in Table 5 and illustrated in Figure 5. Species environment correlations were quite high (Table 5). Although the cumulative percent variance of species data was low, there was a high cumulative percent variance of species-environment relations, which were 44, 67, 74 and 84 for the first 4 axes (Table 5).

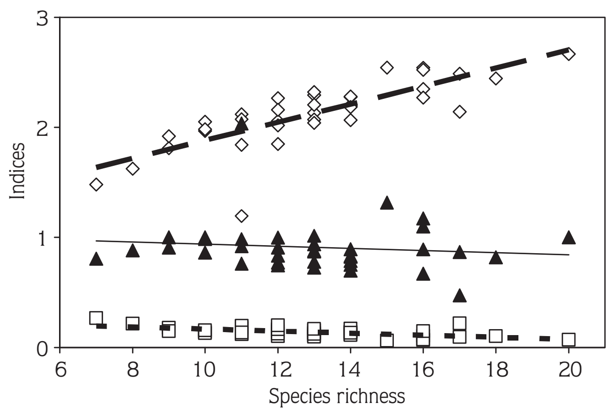

Figure 2. Linear regression between species richness and Shanon's index (*H:* ----- ◊; Y = 1.058 + 0.08231 X, R^2 = 62.7 %, P < 0.001), Simpson's index (*λ*: ….. □; Y = 0.2612-0.009374 X, R^2 = 35.5 %, P < 0.01), and Evenness (*E*5: —— ▲; Y = 1.035-0.00955 X, R^2 = 1.3%, P = 0.505).

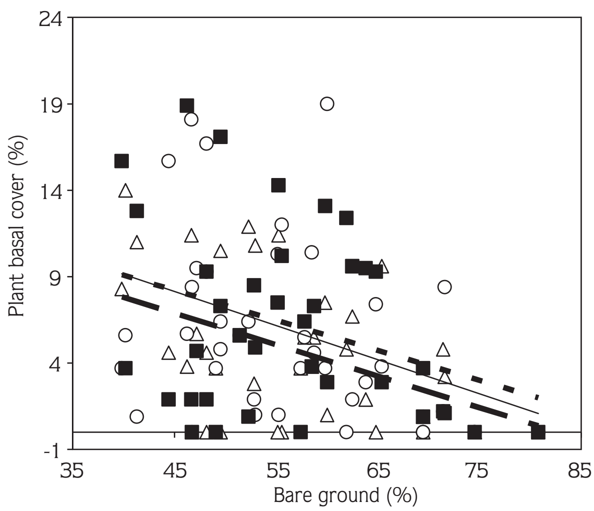

Figure 3. Linear regression between bare ground and *Bromus tomentellus* (----Δ; Y = 15.08-0.1821X, R^2 = 19.2, P < 0.01), *Festuca valesiaca* (—— O; Y = 17.01-0.1973X, R^2 = 14.5%, P < 0.05), and *Thymus sipyleus* (… ■; Y = 16.03-0.1740 X, R^2 = 10.8 %, P < 0.05).

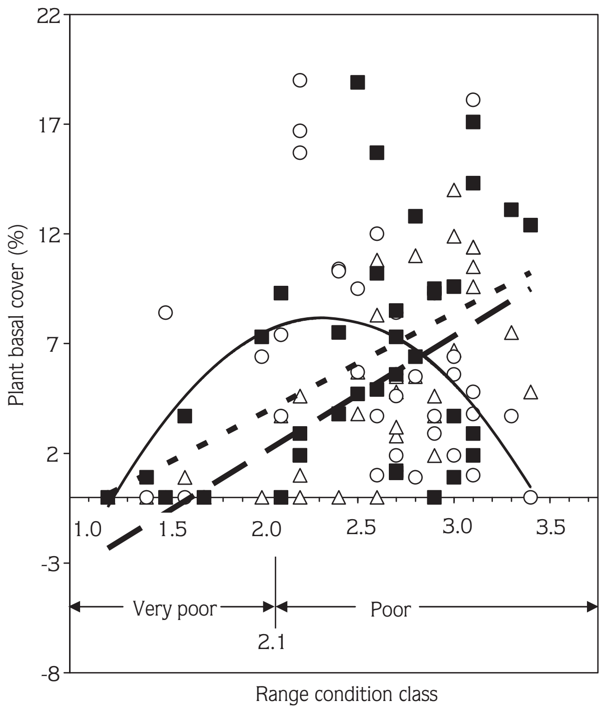

Figure 4. Regression analysis for range condition class with plant basal covers (%) of *Bromus tomentellus* (---- Δ; Y = - 8.775 + 5.376 X, R^2 = 48.8 %, P < 0.001), *Festuca valesiaca* (—— O; Y = - 28.35 + 31.34 X - 6.728 X^2, R^2 = 18.4 %, P < 0.05), and *Thymus sipyleus* (…… ■; Y = -5.402 + 4.601 X, R^2 = 22.0, P < 0.01).

Table 4. Mean, standard error of mean (SEM), and range of some environmental variables for the 37 rangeland sites of the Paşalı village.

Variable	Mean ± SEM	Range
Water saturation (%)	44.16 ± 0.35	40.00 – 48.00
Lime-$CaCO_3$ (%)	11.96 ± 0.48	6.50 - 18.60
P_2O_5 (kg ha^{-1})	81.93 ± 3.60	38.00 - 123.60
K_2O (kg ha^{-1})	305.70 ± 16.90	140.40 - 600.00
Grazing intensity (1-5)	2.38 ± 0.23	1.00 - 5.00
Soil compactness (1-5)	2.95 ± 0.12	2.00 - 4.00
Erosion severity (1-5)	2.32 ± 0.11	2.00 - 5.00
Altitude (m)	1207 ± 4.56	1170.00 - 1260.00

Table 5. Results from Redundancy Analysis (RDA) of species and environment data for the first 4 RDA axes, and significance for the first canonical axis.

Axes	RDA1	RDA2	RDA3	RDA4
Eigenvalues	0.206	0.107	0.049	0.031
Species-environment correlations	0.876	0.766	0.661	0.601
Cumulative percentage variance of species data	20.6	31.3	36.1	39.3
Cumulative percentage variance of species-environment relation	44.1	67.0	74.4	84.0
Total standard deviation in species data	2.12924			
Test of significance for first canonical axis	Eigenvalue=0.206 F-ratio= 6.739 P-value= 0.0020			

The tri-plot of species, sample sites, and environmental data demonstrate the degradation gradient of the range vegetation, which was mainly established on the x-axis (Figure 5). The increase of grazing intensity and soil compactness was evident on the left upper quarter of the tri-plot, because sites 17, 18, 20, 21, 22, and 23 were close to the village (Figure 1). Site 16 nearby the road side (Figure 1) appeared to be an outlier with

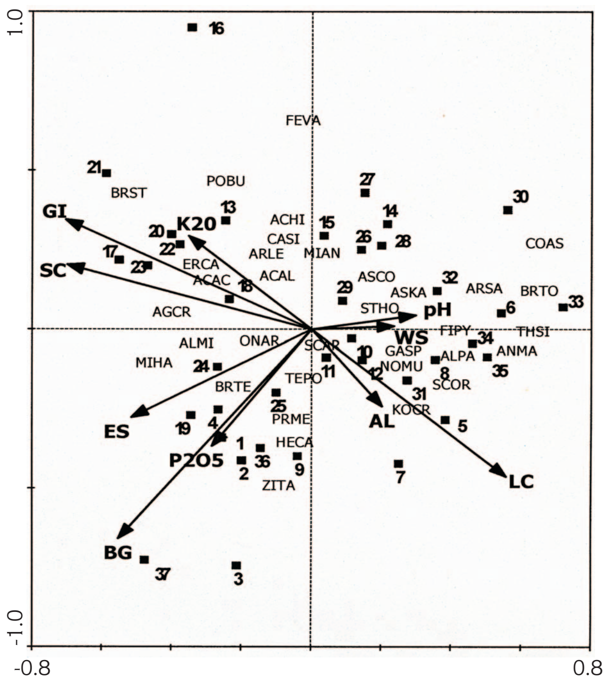

Figure 5. Tri-plot of vegetation, sample (site) and environment variables (soil and management) (GI, grazing intensity; SC, soil compactness; ES, erosion severity; BG, bare ground; P_2O_5, soil phosphorous content; AL, altitude; LC, lime content; WS, water saturation; pH, soil alkaline; K_2O; soil potassium content. Species abbreviations; ACAC (*Acantholimon acerosum*), ACHI (*Acanthus hirsutus*), ACAL (*Achillea aleppica*), AGCR (*Agropyron cristatum*), ALMI (*Alyssum minus*), ALPA (*Alyssum pateri*), ANMA (*Androsace maxima*), ARLE (*Arenaria ledebouriana*), ARSA (*Artemisia santonicum*), ASCO (*Astragalus condensatus*), ASKA (*Astragalus karamasicus*), BRST (*Bromus sterilis*), BRTE (*Bromus tectorum*), BRTO (*Bromus tomentellus*), CASI (*Centaurea sivasica*), COAS (*Convolvulus assyricus*), ERCA (*Eryngium campestre*), FEVA (*Festuca valesiaca*), FIPY (*Filago pyramidata*), GASP (*Galium* sp), HECA (*Helianthemum canum*), KOCR (*Koelaria cristata*), MIAN (*Minuartia anatolica*), MIHA (*Minuartia hamata*), NOMU (*Noaea mucronata*), ONAR (*Onobrychis armena*), POBU (*Poa bulbosa*), PRME (*Prangos meliocarpoides*), SCAR (*Scabiosa argentea*), SCOR (*Scutellaria orientalis*), STHO (*Stipa holosericea*), TEPO (*Teucrium polium*), THSI (*Thymus sipyleus*), ZITA (*Ziziphora taurica*).

high abundance of *Bromus sterilis* (14%) (Figure 5). In the left upper quarter of the tri-plot, excluding *Poa bulbosa* and *Centaurea sivasica*, the other species *Acanthalimon acerosum*, *Acanthus hirsutus*, *Achillea aleppica*, *Agropyron cristatum*, *Arenaria ledebouriana*, *Eryngium campestre,* and *Bromus sterilis* had low abundance and occurrences (Figure 5). *Festuca valesiaca* was distant from any other group because it was placed mid-way on the upper part of the second axis (Figure 5). In the left bottom quarter of the tri-plot, erosion severity and bare ground became apparent, because the bare ground cover of the sites were evidently the highest in that location (Figure 5). Sites 1, 2, and 3 were on abandoned cropping lands (Figure 1). In this quarter of the tri-plot, *Alyssum minus*, *Bromus tectorum*, *Helianthemum canum*, *Minuartia hamata*, *Onobrychis armena*, *Prangos meliocarpoides*, *Teucrium polium*, and *Ziziphora taurica* were the rare species occurring in the range area. In the right bottom of the tri-plot, the lime content substantially increased (Figure 5). The species in this part were *Alyssum pateri*, *Androsace maxima*, *Filago pyramidata*, *Galium* sp, *Koelaria cristata*, *Noaea mucronata*, *Scabiosa argentea*, and *Scutellaria orientalis*. The right upper quarter of the tri-plot contained the species with the highest abundance and appearances across the sites (Figure 5). These species were *Artemisia santonicum*, *Astragalus condensatus*, *Astragalus karamasicus*, *Bromus tomentellus*, *Convolvulus assyricus*, *Minuartia anatolica*, *Stipa holosericea*, and *Thymus sipyleus*. In this quarter, the sites had the least bare ground and were less eroded (Figure 5).

Discussion

Although this is a case study, we consider it to be an important measure of vegetation structure in CAR rangelands. To determine the vegetation structure, which has been constantly subjected to year-round heavy grazing, we have investigated spatial variation in range plant species, groups and associated environmental factors. With respect to heavy grazing, we found out that there was substantial spatial variation in the vegetation structure. While some species appeared to be randomly distributed and a few of them were dominant, others demonstrated correspondence with site differences. This revealed that plant species were responding to the environment in an individualistic manner.

In terms of range plant diversity, there was quite high variation, which was reflected in the abundances of the plant groups (i.e. functional, life spans, and life forms), and major plant species (Table 1, 2, and Appendix). Such differences were most likely to occur due to variations in range conditions associated with soil properties and grazing pressure. Kellner and Bosch (1992) suggested that vegetation patterns in semi-arid grasslands were created through selective grazing by herbivores. It was evident that the forbs, encompassing 77% of total species and 46% of plant cover became the most conspicuous functional group (Table 1). The grasses were the second largest group with 14% of species number and 16% of abundance. These 2 functional groups together constituted 91% of all identified species and formed 81% of the total plant cover in the study area. The perennial life-span group was 90% of the total plant cover. Among plant life-forms, *hemicryptophytes* were 69% of total plant cover and 63% of all species in the study sites. The major species were *Thymus sipyleus* (7.2%), *Festuca valesiaca* (6.9%), *Bromus tomentellus* (6.4%), and *Convolvulus assyricus* (6.02%) (Table 2). These 4 species are resistant to grazing pressure. *Thymus sipyleus*, *Bromus tomentellus,* and *Convolvulus assyricus* were most abundant when plant cover was highest (Figure 5), whereas *Festuca valesiaca* appeared in almost every site.

Milchunas et al. (1988) suggested that arid conditions promote the development of grazing resistance traits. Forbs potentially respond more sensitively to grazing than grasses, because they have a reduced ability to regenerate (Wilmanns, 1998). There might have been greater impacts of grazing on forbs than on grasses, although there were still more forbs than grasses in this study. Forbs were favored when they were prostrate, fast spreading rosette plants (e.g. *Convolvulus holosericieus* and *Onobrychis armena*), sod forming with prostrate stature (e.g. *Convolvulus assyricus*) or upright with defense mechanisms such as chemical compounds (e.g. *Euphorbia mucroclada* and *Peganum harmala*). *Thymus sipyleus* and *Festuca valesiaca* with a prostrate, horizontal growth form were mostly grazing-increaser species, as a group they increased in abundance up to heavy grazing intensities. However, the erect perennial *Bromus tomentellus*, which is readily grazed, successfully regenerates and persists under heavy grazing. Grasses, especially tiller forming grasses (e.g. *Festuca valesiaca*, *Poa bulbosa,* and *Bromus tomentellus*) were encouraged by grazing, as they can -in contrast to forbs- tolerate repeated biomass loss and compensate by re-growth even on nutrient-poor soils (McNaughton, 1982; Crawley, 1992).

The exact nature of the pristine vegetation in this range area is not known, but most probably prior to the vast rangeland to cropping area conversion period of 1950's there was considerably more tall grasses than at present. Overgrazing is assumed to have resulted in a lower density of tall-grasses and a higher density of short grasses and shrubs. In this context, *F. valesiaca* and *T. sipyleus* can be regarded to be as indicator species of disturbances for their extreme resistance to frequent defoliation. Changes in dominant species due to grazing were related to similar independent variables such as changes in species composition (Milchunas and Lauenroth, 1993). The strong negative association of bare ground with the major plant species (Figure 3) and dispersion of the plant species in the tri-plot of the RDA (Figure 5) indicate the importance of spatial pattern in determining vegetation assemblages. Bare ground is another aspect of the range vegetation degradation, which substantially increased as covers of the major plant species decreased (Figure 3).

Range condition scores of the 37 sites were established within a very narrow range, and merely changed from very poor to poor (Figure 4), indicating that severe grazing removed plant species with high quality values or decreased their abundances to very low levels. Though the condition classes cover a very short range, the 3 major range species were significantly correlated to range condition score. *F. valesiaca* had a quadratic relation with an increasing condition score (Figure 4) suggesting that, if range condition moved to fair or good condition, *F. valesiaca* would disappear or be reduced to a few patches. In contrast, *B. tomentellus* and *T. sipyleus* were positively correlated with condition class revealing that they are most likely to become major plant species in resorted rangelands. When disturbances occur regularly and over a long period, plant populations can evolve strategies enabling them to survive the disturbance, and there are many examples of adaptations to permanent or periodically unfavorable conditions (Margalef, 1974). Many of the species identified in this study are unpalatable and invader species. (e.g. *Salvia* sp., *Trigonella* sp., *Conconvulus assyricus* and *Dianthus elegans*), noxious (e.g. *Cardus nutans*, *Eryngium compestre* and *Galium incanum*) or poisonous (e.g. *Euphorbia cardiophylla, Euphorbia macroclada*, *Peganum harmala*). Therefore, we tentatively suggest that some of these patterns may be the result of a long grazing history that has removed some palatable species. However, Koç (1996) positively pointed out that the existence of many unwanted species did not necessarily mean the domination of all these undesirable species; in general a few species with fairly good feeding value had high cover values in the range vegetation.

In our study, simultaneous linear relationships between evenness and species richness data showed that increases in evenness (Shannon's index) were accompanied by increases in species richness (Figure 2). Simpson's index is strongly affected by the importance of the first few species as it is primarily a measure of dominance as degree of concentration of importance values in one or a few species (Whittaker, 1972). Simpson's index (λ) value was significantly and negatively correlated with species richness, indicating that as the number of species increased, domination by a few species decreased (Figure 2).

An increase of the abundances of desirable species, such as *Agropyron cristatum*, *Koelaria cristata*, *Sangiosorba minor*, *Onobrychis armena*, *Bromus tomentollus,* and *Medicago lupilina*, will certainly improve range condition. A significant positive linear relationship of *Bromus tomentellus* cover with the range condition score can pave the way for the condition improvement. It appeared that the spatial scales at which environmental properties vary can differ widely. This is probably typical for CAR steppe rangelands. Noy-Meir (1973) identifies soil heterogeneity and texture as important factors in niche diversification in deserts. Each species is distributed according to its own physiological and life-cycle characteristics and ways of relating to the environment (including other species). In general no 2 species have the same distribution (Whittaker, 1972). Our outcomes were completely in agreement with this idea. Redundancy analysis (RDA) successfully related species and environmental data. The RDA strongly suggested that environmental variables, primarily that of grazing intensity, soil compactness, erosion severity, bare ground, and lime content contributed to an explanation of the strong associations with species data (Table 5 and Figure 5). Our classification result displayed several groups of species, although there were not many environmental differences, indicating that these groupings are most likely to have occurred due to the spatially-varying grazing intensity in the range area. We generally found much greater abundance of plant species on the right half of the tri-plot (Figure 5). Considerable differences were also observed between vegetation near village range areas, with high grazing intensity and soil compactness, and range sites far from the village, with relatively high soil lime content.

In conclusion, our concern here has been to provide information on multiple-scale relationships as they currently exist between vegetation structure, plant diversity, and environmental variables. We have found that plant species composition and diversity are at least somewhat related to the vegetation pattern that occurred due to environmental variation and grazing effect. Hence, it is critical to focus future research on understanding the available alternatives for range vegetation patterns and their consequences for plant composition and diversity in order to improve plant diversity and range condition and to prevent the encroachment of undesirable plant species. To increase the proportion of desirable species, the implementation of deferment grazing- especially until seed set- should be essential, and fertilizer application will contribute robust seed sets. Consequently, as range health improves, pasture productivity should increase.

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Appendix. A list of plant species identified in the study area; their functional groups, life span and life form groups, number of occurrences (N), mean cover and quality value for each.

Species	Code	Functional group	Life span	Life form	N	Mean cover (%)	Plant Quality value
Annual forbs							
Alyssum minus	ALMI	Forb	Annual	*therophytes*	8	3.5	1
Anagallis arvensis	ANAR	Forb	Annual	*therophytes*	1	1.0	1
Androsace maxima	ANMA	Forb	Annual	*therophytes*	7	1.1	1
Anthemis cretica	ANCR	Forb	Annual	*therophytes*	2	0.9	2
Arabidopsis thaliana	ARTH	Forb	Annual	*therophytes*	1	0.9	2
Calendula arvensis	CAAR	Forb	Annual	*therophytes*	1	0.9	2
Ceratacephalus falcatus	CEFA	Forb	Annual	*therophytes*	1	0.9	0
Filago pyramidata	FIPY	Forb	Annual	*therophytes*	4	1.4	2
Heliantemum nummularium	HENU	Forb	Annual	*therophytes*	3	2.8	0
Minuartia hamata	MIHA	Forb	Annual	*therophytes*	7	1.0	1
Sideritis montana	SIMO	Forb	Annual	*therophytes*	1	1.0	1
Trigonella sp	TRSP	Forb	Annual	*therophytes*	1	1.0	2
Valerianella vesicaria	VAVE	Forb	Annual	*therophytes*	2	1,0	1
Xeranthemum annuum	XEAN	Forb	Annual	*therophytes*	2	2.3	1
Ziziphora taurica	ZITA	Forb	Annual	*therophytes*	6	1.9	2
Carduus nutans	CANU	Forb	Biennial	*hemicryptophytes*	1	0.9	0
Perennial forbs							
Acanthus hirsutus	ACHI	Forb	Perennial	*hemicryptophytes*	7	3.1	0
Achillea aleppica	ACAL	Forb	Perennial	*hemicryptophytes*	6	1.9	2
Achillea willhelmsii	ACWI	Forb	Perennial	*hemicryptophytes*	2	11.1	2
Alyssum alyssoides	ALAL	Forb	Perennial	*hemicryptophytes*	1	2.9	1
Alyssum pateri	ALPA	Forb	Perennial	*hemicryptophytes*	29	2.7	2
Arenaria ledebouriana	ARLE	Forb	Perennial	*hemicryptophytes*	6	1.9	2
Astragalus condensatus	ASCO	Forb	Perennial	*chamaephytes*	25	2.8	0
Astragalus karamasicus	ASKA	Forb	Perennial	*hemicryptophytes*	20	2.0	2
Astragalus nitens	ASNI	Forb	Perennial	*hemicryptophytes*	1	1.9	2

Centaurea sivasica	CASI	Forb	Perennial	*hemicryptophytes*	22	3.0	2
Cardaria draba	CADR	Forb	Perennial	*hemicryptophytes*	1	0.9	1
Centaurea carduiformis	CECA	Forb	Perennial	*hemicryptophytes*	1	1.9	0
Convolvulus assyricus	COAS	Forb	Perennial	*hemicryptophytes*	30	6.0	2
Convolvulus lineatus	COLI	Forb	Perennial	*hemicryptophytes*	3	5.5	1
Dianthus elegans	DIEL	Forb	Perennial	*hemicryptophytes*	2	0.9	1
Eryngium campestre	ERCA	Forb	Perennial	*hemicryptophytes*	10	0.9	0
Euphorbia cardiophylla	EUCA	Forb	Perennial	*geophytes*	1	0.9	-1
Euphorbia macroclada	EUMA	Forb	Perennial	*hemicryptophytes*	2	0.9	-1
Galium incanum	GAIN	Forb	Perennial	*chamaephytes*	1	1.0	0
Galium sp	GASP	Forb	Perennial	*hemicryptophytes*	9	1.6	0
Gundelia tournefortii	GUTO	Forb	Perennial	*hemicryptophytes*	1	0.9	0
Helianthemum canum	HECA	Forb	Perennial	*hemicryptophytes*	5	3.0	2
Helichrysum arenarium	HEAR	Forb	Perennial	*hemicryptophytes*	1	0.9	1
Hieracium sp	HISP	Forb	Perennial	*hemicryptophytes*	1	0.9	1
Hypericum avicularifolium	HYAV	Forb	Perennial	*hemicryptophytes*	1	1.0	0
Malva neglegta	MANE	Forb	Perennial	*hemicryptophytes*	1	0.9	3
Medicago lupulina	MELU	Forb	Perennial	*hemicryptophytes*	1	1.2	6
Minuartia anatolica	MIAN	Forb	Perennial	*hemicryptophytes*	9	1.1	1
Moltkia caerulea	MOCA	Forb	Perennial	*hemicryptophytes*	3	4.0	1
Onobrychis armena	ONAR	Forb	Perennial	*hemicryptophytes*	8	0.9	5
Paronychia kurdica	PAKU	Forb	Perennial	*hemicryptophytes*	1	0.9	0
Peganum harmala	PEHA	Forb	Perennial	*hemicryptophytes*	2	6.9	-1
Potentilla sp	POSP	Forb	Perennial	*hemicryptophytes*	1	0.9	1
Prangos meliocarpoides	PRME	Forb	Perennial	*geophytes*	4	1.5	6
Ranunculus sp	RASP	Forb	Perennial	*hemicryptophytes*	1	1.0	0
Salvia sp	SASP	Forb	Perennial	*hemicryptophytes*	1	0.9	2
Sanguisarba minor	SAMI	Forb	Perennial	*hemicryptophytes*	1	1.0	6
Scabiosa argentea	SCAR	Forb	Perennial	*hemicryptophytes*	7	1.2	1
Scorzonera mollis	SCMO	Forb	Perennial	*geophytes*	1	1.0	1
Scutellaria orientalis	SCOR	Forb	Perennial	*hemicryptophytes*	6	0.9	3
Taraxacum officinale	TAOF	Forb	Perennial	*hemicryptophytes*	1	1.9	4
Teucrium polium	TEPO	Forb	Perennial	*hemicryptophytes*	5	2.1	1
Tragopogon dubius	TRDU	Forb	Perennial	*hemicryptophytes*	1	1.0	2
Verbascum vulcanicum	VEVU	Forb	Perennial	*hemicryptophytes*	1	1.0	0
Annual grasses							
Bromus japonicus	BRJA	Grass	Annual	*therophytes*	2	0.9	1
Bromus sterilis	BRST	Grass	Annual	*therophytes*	7	8.7	1
Bromus tectorum	BRTE	Grass	Annual	*therophytes*	4	1.3	1
Taenitherum caput-medusae	TACM	Grass	Annual	*therophytes*	3	4.0	1
Perennial grasses							
Agropyron cristatum	AGCR	Grass	Perennial	*hemicryptophytes*	8	2.7	8
Briza media	BRME	Grass	Perennial	*hemicryptophytes*	1	1.0	1
Bromus tomentellus	BRTO	Grass	Perennial	*hemicryptophytes*	28	6.4	6
Festuca valesiaca	FEVA	Grass	Perennial	*hemicryptophytes*	32	6.9	3
Koelaria cristata	KOCR	Grass	Perennial	*hemicryptophytes*	9	1.9	7
Poa bulbosa	POBU	Grass	Perennial	*hemicryptophytes*	21	2.8	4
Stipa holosericea	STHO	Grass	Perennial	*hemicryptophytes*	5	1.0	3
Shrubs							
Acantholimon acerosum	ACAC	Shrub	Perennial	*chamaephytes*	7	2.0	0
Artemisia santonicum	ARSA	Shrub	Perennial	*hemicryptophytes*	17	2.0	1
Fumana procumbens	FUPR	Shrub	Perennial	*chamaephytes*	3	1.6	1
Globularia orientalis	GLOR	Shrub	Perennial	*chamaephytes*	2	2.3	3
Kochia prostrata	KOPR	Shrub	Perennial	*chamaephytes*	1	1.0	3
Noaea mucronata	NOMU	Shrub	Perennial	*hemicryptophytes*	7	1.6	2
Thymus sipyleus	THSI	Shrub	Perennial	*chamaephytes*	32	7.2	3